Title: **IMAGE ANALYSIS TECHNIQUES FOR IMAGE SEGMENTATION AND IMAGE INPAINTING PROBLEMS: A MATHEMATICAL APPROACH**

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SYNOPSIS

The present thesis submitted for Ph.D. degree entitled "**Image Analysis techniques for Image Segmentation and Image Inpainting problems: A Mathematical Approach**",is an outcome of the interdisciplinary study of relevant fields based on mathematics, statistics, especially partial differentially equations, calculus of variations, Numerical methods and computer programming in MATLAB.

Segmentation of images and image Inpainting are major task for image analysis and image restoration respectively in the field of image processing. Here, digital image processing is an area characterized by the need for extensive experimental work to establish the viability of proposed solutions to a given problem. In this thesis we outline how a theoretical base and state of the art software can be integrated into a prototyping environmental whose objective is to provide a set of well supported tools for the solution of a broad class of problems in digital image processing. An image is denoted as two dimensional functions of the form $f(x, y)$. The value of the amplitude of f at a spatial coordinates (x, y) is a positive quantity whose physical meaning is determined by the source of the image. In a digital image, (x, y), and the amplitude of f are all finite and discrete quantities. The digitization process includes sampling and quantization of continuous data. The sampling process samples the intensity of the continuous-tone image, such as a monochrome, colour or multi-spectrum image, at specific locations on a discrete grid. The grid defines the sampling resolution. The quantization process converts the continuous or analog values of intensity brightness into discrete data, which corresponds to the digital brightness value of each sample, ranging from black, through the gray, to white. A digitized sample is referred to as a picture element, or pixel.

Image processing techniques enhancement and restoration take a digital image as input and gives out another image that is of improved quality. On the other hand, in image analysis technique, the same input gives out somewhat detail description of the scene whose image is being considered. Most of the image analysis algorithms perform segmentation as a first step towards producing the description. Here input and output are still images, but output is an abstract representation of the input. Segmentation technique basically divides the spatial domain, on which the image is defined, into meaningful parts or regions. This meaningful region may be complete object or may be a part of it. The segmentation algorithms try to make systematic use of some physically measured image features, but its performance is measured based on the meaning associated with the extracted regions. So we may consider segmentation as psycho-physical problem. Secondly, the requirement that the extracted region must have some meaning with respect to the given scene or an object in it makes the problem mathematically ill-posed. As a result, there exists no general segmentation algorithm suitable for the problem in hand. So, all the segmentation algorithms are adhoc in nature. That is, segmentation should stop when the objects of interest in an application have been isolated.

Overview of Image Segmentation and Image Inpainting Problems:

In thisthesis, we studied two different section of digital image processing i.e. image segmentation and image inpainting. We first consider the image segmentation. Here,segmentation of nontrivial images is one of the most difficult tasks in image processing. Segmentation accuracy determines the eventual success or failure of computerized analysis procedures. For this reason, considerable care should be taken to improve the probability of rugged segmentation. In some situations, such as industrial inspection applications, at least some measure of control over the environment is possible at times. The experienced image processing system designer invariably pays considerable attention to such opportunities. In other applications, such as autonomous target acquisition, the system designer has no control of the environment. Image segmentation algorithms generally are based on one of the two basic properties of intensity values: discontinuity and similarity. In the first category, the approach is to partition an image based on abrupt changes in intensity, such as edges in an image. The principal approaches in second category are based on partitioning an image into regions that are similar according to a set of predefined criteria. Thresholding, region growing, and region splitting and merging are examples of methods in this category.

More generally, image segmentation is the problem of partitioning an image in a semantically meaningful way. This vague definition implies the generality of the problem segmentation can be found in any image-driven process, e.g. fingerprint/text/face recognition, detection of anomalies in industrial pipelines, tracking of moving people/cars/airplanes, etc. For many applications, segmentation reduces to finding an object in an image. This involves partitioning the image into two classes of regions either object or background. Segmentation is taking place naturally in the human visual system. We are experts on detecting patterns, lines, edges and shapes, and making decisions based upon the visual information. At the same time, we are overwhelmed by the amount of image information that can be captured by today's technology. It is simply not feasible in practice to manually process all the images (or it would be very expensive, and boring, to do so). Instead, we design algorithms which look for certain patterns and objects of interest and put them to our attention. For example, a recent popular application is to search and match known faces in your photo library which makes it possible to automatically generate photo collections with a certain person. An important part of this application is to segment the image into "face" and "background". This can be done in a number of ways, and it is well accepted that no general purpose segmentation algorithm exists, or that it ever will be invented.

In second session,we focus on some little idea of image restoration problemfor digital image inpainting in the field of image processing.Image inpainting is an iterative method for repairing damaged pictures or removing unnecessary elements from pictures. This activity consists of filling in the missing areas or modifying the damaged images in a non-detectable way by an observer not familiar with the original images. Medieval artwork started to be restored as early as the Renaissance, the motives being often as much to bring medieval pictures "up to date" as to fill in any gaps. This practice is called retouching or inpainting. The object of inpainting is to reconstitute the missing or damaged portions of the work, in

order to make it more legible and to restore its unity. There are various real world situations where an image or photograph is damaged due to aging. The historical paintings in temples torn photographs of ancient history etc. are few examples. The reconstruction of damaged images in a way that is undetectable for an observer who does not know the original image is known as inpainting.

The story of inpainting begins in the art world. For centuries, people have been keenly interested in repairing missing sections of oil paintings, and doing so in a way that renders the restoration as imperceptible as possible. However, differences of opinion regarding the best way to accomplish the retouching have been present from art restoration's inception. Inpainting of artworks began as early as the Renaissance. Much of the existing artwork for this period came from the Roman era, and was badly in need of repair. These crucifixions and sundry religious scenes were restored by 14^{th}century artists who softened the Roman style to their own tastes, often inpainting blue skies in a blank region where a gold colouring had previously lay.

There is no standard definition for image inpainting. Roughly speaking, the purpose of image inpainting is to remove an object from an image. The key point is how to make the image appear like the object never existed. Digital image inpainting is a technique that restores an image by smoothly filling a hole in a purely automatic fashion. In the literature, another application of image inpainting is described to repair a damaged picture. That means, for a scratched image, how can we restore so that it exhibits its undamaged appearance? Applications of image inpainting range from restoration of photographs, films and paintings, to removal of occlusions, such as large unwanted regions, superimposed text, subtitles, stamps and publicity, from images. In addition, it is of significant importance in restoration of precious work of arts, calligraphies, and paintings in the digital museum with image inpainting technique.

Objective:

Generally image segmentation is partition of an image into a set of disjoint regions with uniform and homogeneous attributes such as intensity, colour, tone or texture etc. In many real situations, for images, issues such as limited spatial resolution, poor contrast, overlapping intensities, noise and intensity inhomogenities we have insufficient result. Due to this introduce active contours modelto detect the required object in image. Also,we focus on image inpainting problems based on restoration aspects. In short the different applications of digital image processing have been presented in this thesis and we concentrate on how a mathematical approach performs in the area of image segmentation and image inpainting.

The present work is divided into eight chapters. The brief description of each chapter is given below.

CHAPTER-1:

This chapter gives an introduction and overview of digital image processing and image analysis techniques. Here we also discussed two major areas, one is image segmentationand another is image inpainting (restoration) with their origination, definition, applications, literature review about research going on image analysis techniques [1]. It also discusses on problem statements of proposed methodology and its objectives with applications.

CHAPTER-2:

This chapter is based on the mathematical techniques that present a subset of tools, which are most frequently used in image processing and analysis. It is often necessary and convenient to characterize images mathematically for understandingand designing image processing algorithms [2, 3]. Mathematical characterization is of utmost importance for better presentation of the problem, and subsequently, for determining an acceptable solution with experimental results using Matlab. Our main concernis to study the partial differential equations (PDE) and calculus of variations methods related to image processing.

CHAPTER-3:

This chapter deals with detail description of traditional image segmentation techniques say gradient, thresholding etc. Generally image segmentation is an essential step in almost all image analysis systems. Segmentation is the problem of partitioning image domain into meaningful regions. Here, we discussed two main approaches in image segmentation: edge- and region- based. Edge based segmentation partitions an image based on discontinuities among sub-regions, while region-based segmentation does the same function based on the uniformity of a desired property within a sub-region. We briefly discussed existing image segmentation technologies as background.

CHAPTER-4:

This chapter introduces an important method of image segmentation known as active contours. We studied two main approaches in active contours based on the mathematic implementation: snakes and level sets. Snakes explicitly move predefined snake points based on an energy minimization scheme, while level set approaches move contours implicitly as a particular level of a function. We also discussed advantages of active contours over other segmentation methods, theoretical background of active contours and an overview of existing active contour methods.

CHAPTER-5:

In this chapter we discussed the Chan-Vese Active contours models that shows how to detect the object in given image. Generally, there are a lot of image segmentation techniques that try to differentiate between backgrounds and object pixels but many of them fail to discriminate between different objects that are close to each other, e.g. low contrast between foreground and background regions increase the difficulty for segmenting images.

So that's why we introduced the Chan-Vese active contours model for image segmentation, which is built based on techniques of curve evolution and level set method. The Chan-Vese model is a special case ofMumford-Shah functional for segmentation and level sets [4, 5]. It differs from other active contour models is not edge dependent, therefore it is more capable of detecting objects whose boundaries may not be defined by a gradient. The resulting partial differential equation (PDE) is solved by using finite difference scheme through Matlab.

CHAPTER-6:

In this chapter, we apply a new Mathematical approached to develop a novel image segmentation method using active contours on noisy images with fifteen percentages of salt and pepper noise selective binary and Gaussian filtering method to regularize level set evolution [6]. Normally we selectively penalize the level set function to be binary and then use a Gaussian smoothing kernel to regularize it.

Also, we proposed a new region based signed pressure force (SPF) function, which can step effectively the contour at blurred as well as weak edges and automatically detect the interior and exterior boundaries with the initial contour being anywhere in the images affected with noise. Also we demonstrate the advantages and comparison of the proposed method over the Chan-vase active contour model that we discussed in previous chapter. Finally, we implement our mew method by the finite difference scheme with experiment results through Matlab.

CHAPTER-7:

In this chapter we slightly change our direction to image inpainting problems. So first we defined definition, different types of methods, limitations, advantages, usefulness in this chapter. Generally image inpainting fills the missing or damaged region in an image utilizing spatial information of its neighbouring region. It is helpfully used for different applications of restoration of old films, object removal in digital photographs, red-eye correction, super resolution, compression etc. We also discussed a brief comparative study of different image inpainting techniques.

CHAPTE-8:

In this last chapter of the thesis we have explored a new approach for image restoration. Generally image inpainting and denoising refers to the ill-posed problem of filling in the missing data in digital images by interpolatingfrom the vicinity [8]. The denoising is performed by the smoothing equation working inside and outside of the inpainting domain but in completely different ways.

Inside the inpainting domain, the smoothing is carried out by the Mean Curvature Flow, while outside the inpainting domain is carried out in a way as to encourage smoothing within a region and discourage smoothing across boundaries which described by diffusion equations [7]. The approach here presented permits the transportation of available

information from the outside towards the inside of the inpainting domain. Finally we illustrate the effective performance of our model with some experimental results perform in Matlab.

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